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Your Ref. : PAC

24 November 1999

PATENT APPLICATION NUMBER 9927674.3

The Patent Office confirms receipt of a request for grant of a patent, details of which have been recorded as follows :

Filing Date (See Note)	:	23-NOV-99
Applicants	:	Aegis Engineering Limited, Du Pont de Nemours International S.A.
Description (No.of Sheets)	:	12
Claims (No.of Sheets)	:	None
Drawings (No.of Sheets)	:	None
Abstract	:	None
Statement of Inventorship (Form 7/77)	:	None
Request for Search (Form 9/77)	:	None
Request for Examination (Form 10/77)	:	None
Priority Documents	:	None
Translation of Priority Documents	:	None
Divisional of Application	:	None
Divisional Date Claimed	:	
Other Attachments Received	:	None

The application number included in the heading above should be quoted on all correspondence with The Patent Office.

Any queries on this receipt should be addressed to Sarah Handy, tel 01633 814570.

Note : The above filing date is provisional and may need to be amended if the provisions of section 15(1) of the Patents Act 1977 are not met.

Patents Form 1/77

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Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

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1. Your reference — PAC

2. Patent application number
(The Patent Office will fill in this part)

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Aegis Engineering Limited

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Patents ADP number *(if you know it)*

If the applicant is a corporate body, give the country/state of its incorporation — United Kingdom

& Du Pont de Nemours International S.A.

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Geneva
Switzerland

Switzerland

4. Title of the invention — PROTECTIVE MATERIAL.

5 Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

A A THORNTON & CO

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LONDON WC1V 7LE

Patents ADP number *(if you know it)* — 0000075001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body
See note (d))

YES

Patents Form 1/77

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	—
Description	12
Claim(s)	—
Abstract	
Drawing(s)	—

10. If you are also filing any of the following, state how many against each item.

Priority documents	—
Translations of priority documents	—
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	—
Request for preliminary examination and search *(Patents Form 9/77)*	—
Request for substantive examination *(Patents Form 10/77)*	—
Any other documents *(please specify)*	—

11. I/We request the grant of a patent on the basis of this application.

Signature: A. A. Thornton & Co. Date: 23 November 1999

12. Name and daytime telephone number of person to contact in the United Kingdom: Philip A. CURTIS - 0171 440 6860

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Notes

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b) *Write your answers in capital letters using black ink or you may type them.*

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PROTECTIVE MATERIAL

This invention relates to a protective material. The invention particularly relates to coated or laminated Kevlar (Registered Trade Mark) fabrics having continuous filament fibres for stab, slash and puncture resistance applications.

There exists market need for protection against knife threats with lightweight and flexible system solutions. Typical vests made of soft, uncoated Kevlar fabrics, eg., NIJ IIIA ballistic vest made of 840 denier Kevlar fibre at 1.4 psf, were know to be inadequate for the protection against the commercially made or engineered sharp-edged knives such as the UK PSDB P1 and Russel boning knife etc.

The current situation, as disclosed in the prior art, for knife threat protection includes basically the following two material systems:

(1) flexible metallic plates or metallic chainmails

(2) coated fabrics, e.g. aramid fabric coated with silicone particles, thermoplastic and thermosetting resins. The basic idea was to increase the hardness of the vest to dull the tip or sharp edge of the knife.

However, the flexible metallic components tend to increase the weight of the vests and tend not to be resistant to sharp-tipped threats such as hypodermic needles and ice-picks. On the other hand, the coated fabrics tend to be rigid, inflexible and comfortable. Currently, coated aramid fabrics for anti-stab purposes either commercially or disclosed in the prior are almost exclusively based a fabric woven with fibres of greater than 840 denier. For example, the Twaron SRM which is a coated aramid fabric for anti-stab purpose is based on the 840 denier Twaron microfilament, coated with 200 g/m2 of a mineral material. In consequence the material is bulky, inflexible and heavy.

We have found that in a coated fabric form, the stab-resistance is dramatically increased if Kevlar fabric of lower denier is used. In addition, the resultant vests become much more flexible and thinner. By lower denier, it is meant by fibres of less than 600 denier.

In one aspect, the present invention provides a protective material comprising at least one layer of layer comprising a plurality of fibres capable of resisting penetration by a bullet or a knife, and a support material, wherein at least part of said fibres are embedded within the support material to restrict relative movement of the fibres therein, and wherein the fibres have a denier below 840.

In another aspect, the present invention provides a protective material comprising at least one layer of comprising a plurality of fibres capable of resisting

penetration by a bullet or a knife, and a support layer laminated with the or each fibrous layer wherein the fibres of the fibrous have a denier below 840. In this aspect of the invention, the fibrous layer need not necessarily be embedded in the support layer.

In both the above aspects of the invention, the layers are advantageously flexible. The layers may be sufficiently flexible that they are not capable of supporting their own weight.

We have obtained especially good results when the denier of the fibres is less than or equal to about 600. Even better results have been achieved when the denier of the fibres is less than or equal to about 400. In an embodiment, the denier is less than 400. The minimum practical value of the denier is about 30-40, but we prefer that the denier is 100 or more, preferably 150 or more. We have obtained vary good results in the denier range from 200 to 400.

Preferably there are at least two layers. In general, we prefer to provide from 5 to 50 layers, more preferably 10 to 50 layers. However, we have found that 10 to 20 layers is usually sufficient.

The support material is preferably coated or laminated with a resin solution or resin film. The resin may be a thermoplastic resin such as ionic polyethylene (Surlyn, low density polyethylene, a phenolic resin (e.g. a mixture of phenolic poly(vinyl butral), an epoxy resin or mixtures thereof. The resin preferably comprises 12 to 50% of the total weight of the fibres and resin.

This invention involves the use of fabrics, particularly Kevlar fabrics, woven with low denier fibres. Examples of such fabric are currently commercial or semi commercial with the following types;

Denier	Ends/inch	Dry weight (g/m2)
200	36.5 x 36.5	60
400	31 x 31	105
400	36.5 x 36.5	120
600	31 x 31	160
600	29 x 29	158

The present invention provides a fabric that can be used in protective garments including, knife protection vests, bulletproof vests and multiple threat vests. The material is preferably included as a multiple-sheet pack. The material can be

used in conjunction with other protective materials, such as unresinated soft Kevlar (RTM) fabric to form a multiple-threat vest. The protective material can be sown into the rest of the garment, or it can be provided in a pack which is sown into the garment. Alternatively, the protective material (or a pack containing it), may simply be placed inside an suitable sized pocket provided in the garment.

The protective material according to the invention provides (preferably in conjunction with Kevlar ballistic soft fabrics and Kevlar Correctional) an excellent lightweight and flexible multi-threat vest against knives, ice-picks, hypodermic needles and bullets with, preferably, 100% Kevlar fibres.

The following examples further illustrate the invention.

Test Method:

Based on UK PSDB Standard for Stab Resistant Body Armour (1999). The PSDB single-edge blades were used and a composite of neoprene/foam/rubber was used as the backing material.

The resinated Kevlar fabrics were tested in conjunction with a soft ballistic pack which meets the UK PSDB Handgun I Level (equivalent to NIJ II with 25 mm of backface deformation allowed). All resinated fabric were coated with an epoxy resin.

The results are presented in terms of areal density of the pack required to meet the three stab levels defined in the PSDB (1999) Standards.

Table 1. Areal Density Required to Defeat PSDB HG1/KR1 (24 Joule at 7 mm penetration)

Construction of the test packs:

Style: Kevlar fabric 1 (K-129, 185 g/m2)
Stab Pack (using 200, 400, 840, 1500, 3000 denier resinated Kevlar fabrics)

Results

Pack No	Layers	Ballistic AD kg/m2	Stab-Pack	Layers	A.D. (kg/m2) Resinated	Total A.D. for HG1/KR1 (kg/m2)
1	23	4.26	200 D	15	2.00	6.26
2	23	4.26	400 D	10	2.24	6.50
3	23	4.26	840 D	9	3.08	7.34
4	23	4.26	1500 D	7	3.53	7.79
5	23	4.26	3000 D	6	4.70	8.96

The above table shows that, under the identical pack construction, to stop the PSDB P1 Knife at 24 joules with less than 7 mm penetration, the higher the denier, the higher the resinated fabric weight is required. Fabrics of below 400 denier shows a dramatic improvement in stab-resistance.

Table 2 ——-Areal Density Required to Defeat HG1/KR2 (36 Joules and less than 7 mm penetration)

Pack No	Layers	Ballistic AD kg/m2	Stab-pack	Layers	A.D. (kg/m2) Resinated	Total A.D. for HG1/KR2 (kg/m2)
1	23	4.26	200D	18	2.29	6.54
2	23	4.26	400D	13	2.74	7.00
3	23	4.26	840D	13	3.86	8.12
4	23	4.26	1500D	11	4.89	9.14
5	23	4.26	3000 D	8	5.74	10.00

Here, to stop the knife at 36 joules with less than 7 mm trauma, the improvement with low denier fabrics are even more marked.

Table 3 ——Areal Density Required to Defeat HG1/KR3 (65 joules at less than 20 mm penetration)

Pack No	Layers	Ballistic AD kg/m2	Stab-pack	Layers	A.D. (kg/m2) Resinated	Total A.D. for HG1/KR2 (kg/m2)
1	23	4.26	200D	36	3.68	7.94
2	23	4.26	400D	23	4.08	8.34
3	23	4.26	840D	16	4.70	8.96
4	23	4.26	1500D	13	5.74	9.99
5	23	4.26	3000D	9	6.43	10.69

Note:

Ballistic component content of Kevlar fabric 1 is woven 930dtex Kevlar 129, woven to 185g/m2 (dry weight)

It will be appreciated that the invention may be modified.

This invention is applicable to the protective material described in UK patent number 2304350, a copy of the specification of which is set out below, and which forms a part of the specification for the present application. This patent specification was published on 30th June 1999.

In particular the present invention can be applied to all the matter of GB-B-2304350, subject to the denier of the fibres being below 840, more preferable equal to or below 600, and most preferably equal to or below 400. It should also be noted that when applying the present invention to the disclosure of GB-B-2304350, it is not necessarily essential to provide more than one flexible layer, although this is preferred. Also, it is not essential in the present invention that the layers are separate, but, again, this feature is preferred.

SPECIFICATION FOR UK PATENT NUMBER 2304350

This invention relates to a protective material.

It is known to use personal body armour to give protection against a wide variety of threats. This armour typically comprises a pack containing layers of woven aramid fibre.

In order to provide the capability to resist multiple hits from projectiles it is usual to stitch or quilt the layers together; this helps to prevent "bunching", which causes the layers to bunch up together, and progressively reduces the protection after each hit.

It is also known to provide additional material to reduce the trauma effect caused to the wearer by the impact of the projectile. The additional material may comprise, for example, one or more layers of plastic or rubber foam; one or more polyolefin sheets; or one or more packs of feathers.

When protection from knife impact is also required it is usual to add a still further layer, which comprises, for example, metal meshes; lightweight metal panels; or overlapping medallions of lightweight metal.

It will be appreciated that each protective layer adds to the thickness and weight of the armour, thereby reducing its wearability.

According to one aspect of the present invention there is provided a protective material comprising a plurality of separate flexible layers each layer comprising a plurality of fibres capable of resisting penetration by a bullet or a knife, and a support

material, wherein at least part of said fibres are embedded within the support material to restrict relative movement of the fibres therein.

Advantageously the support material is a resin, more preferably a synthetic resin, and most preferably a thermosetting resin. The precise resin used depends upon the final application of the material: an epoxy-based resin, a phenolic-based resin or a polyester-based resin is preferred. It is also preferred that the support material has sufficient rigidity to enable the or each flexible layer to support its own weight.

The fibres are typically of the type that have a high tensile strength and a high stretch resistance. The fibres may comprise high strength polyethylene fibres, glass fibres, or carbon fibres. In the preferred embodiment the fibres comprise aramid fibres, particularly fibres of poly(p-phenylene terephthalamide). When aramid fibres are used, they may, for example, comprise the fibres sold under the registered trade names KEVLAR or TWARON.

In one embodiment, the fibres are woven to form a fabric, prior to being embedded in the support. In another embodiment, the fibres are arranged in a unidirectional manner, i.e., they are not woven.

Preferably the protective material contains 20-50 wt% of the support material, most preferably 33 wt%.

It is preferred that the fibres are substantially entirely embedded in the support material, because this provides the best resistance to penetration by a knife or similar object.

There are a number of parameters of the protective material which depend upon the use to which it will be put, and also on the type of fibres and support material used. These parameters include the number of flexible layers, the thickness of each flexible layer, and the denier of the fibres. Typically, there will be between 5 and 50 layers, each having a thickness between 0.2mm and 0.5mm, with the fibres having a denier between 400 and 1500.

The most preferred fibres are available from Du Pont under the registered trade name KEVLAR 129 (or KEVLAR HT). Using these fibres, together with a resin comprising a blend of bisphenol A and bisphenol F, the denier of the fibres is most preferably 840, the thickness of each layer is preferably 0.25mm and the number of layers is preferably 26. This will provide a level of protection that can prevent penetration by hand gun bullets, and can provide adequate protection against trauma; it will also provide protection against a knife strike having an energy of 42 Joules, or

more. The material is capable of meeting applicable standards set by the British Home Office.

In order to provide sufficient protection against high velocity bullets the protective material may include at least one layer of ceramic plates, such as alumina plates. It will be appreciated that other materials, known to those skilled in the art, may be used to provide protection against high velocity bullets.

The protective material according to the invention is particularly useful as personal body armour. For example, it can be provided in the form of, or as part of, a vest or jacket for providing body protection to the front and/or the back; it may be provided in the form of, or as part of, any other garment to protect any other part of the body, for example the arms or the legs. The protective material may be provided in the form of, or as part of, headwear, such as a helmet; or it may be provided in the form of, or as part of, footwear, such as boots. The protective material may be provided in the form of, or as part of, a hand-held shield.

The protective material may be provided in the form of a pack that can be removably secured to a garment. It may be incorporated into an existing protective garment by mixing with or adding to protective layers already in the garment - this will enhance the performance of the protective layers already present.

The protective material according to the invention may instead be used as armour for vehicles, ships, aeroplanes or buildings. It is possible to protect against a wide variety of ballistic threats with the protective material according to the invention. The material can also provide adequate protection against trauma, without the need to use any additional layer of a different material. The material is also capable of preventing penetration by a knife or other sharp instrument.

The material is resistant to the problem of bunching, discussed above, due to the ability of each layer to support its own weight, so it is not necessary to stitch or quilt together multiple flexible layers.

In one embodiment, the protective material can be made by preimpregnating the fibres with a resin, then subsequently curing the resin by heat and pressure (typically from 100 to 150 degrees C and 50 to 150 psi [345 to 1035 KPa]). The pre-impregnated fibres may be stored and/or transported, preferably in roll form before they are finally cured.

In another embodiment, the protective material may be made by impregnating the fibres with a resin, followed by curing shortly thereafter. In this embodiment a low viscosity epoxy resin is preferred, such as a resin manufactured from epichlorohydrin

with a blend of bisphenol A and bisphenol F (this is available from ASTOR STAG as product type 629), and a suitable curing agent. The curing agent may be a polyalkyamine; one example of a suitable curing agent is available from ASTOR STAG as product type RS 4025. An entire roll, or part of a roll, of the fibres may be dipped in resin to coat either the entire roll or part of the roll. The resin can be cured at ambient temperature under a pressure of 10 to 20 psi (69 to 138 KPa).

In both embodiments, the impregnated material can be cut into sheets either before or after curing. When the material is cut into sheets before curing, then between 5 and 50 sheets may be placed on top of one another with a release film between each layer. The release film may be, for example, mylar (RTM), a polyolefin film, or a silicone-coated paper. The multiple sheets can then be cured; after curing the sheets are separated, and the release film is either discard or re-used.

A plurality of the layers may then be used to from the protective material described above. The material may then be used on its own, or may be added to standard ballistic fabrics in order to improve the performance thereof.

The impregnated material can be shaped before it is cured, for example, in a mould. If desired, the impregnated material can be cured in the mould. One reason to shape the material is to provide a shape suitable to be worn by a woman.

Whilst certain embodiments of the invention have been described above it will be appreciated that modifications, not described above, could be made to the invention.

CLAIMS: (FOR GB-B-2304350)

1. A protective material comprising a plurality of separate flexible layers each layer comprising a plurality of fibres capable of resisting penetration by a bullet or a knife, and a support material, wherein at least part of said fibres are embedded within the support material to restrict relative movement of the fibres therein.

2. A protective material according co claim 1, wherein the support material is a resin.

3. A protective material according to claim 1, wherein the support material is a synthetic resin.

4. A protective material according to claim 1, wherein the support material comprises a thermosetting resin.

5. A protective material according to any preceding claim wherein the support material is an epoxy-based resin, phenolic-based resin or a polyester-based resin.

6. A protective material according to any preceding claim, wherein the fibres comprise polyethylene fibres, glass fibres, carbon fibres or aramid fibres.

7. A protective material according to claim 6, wherein the fibres comprise fibres of poly(p-phenylene terephthalamide).

8. A protective material according to any preceding claim, wherein the support material comprises 20-50 wt % of the protective material.

9. A protective material according to any preceding claim comprising between 5 and 50 of said flexible layers.

10. A protective material according to any preceding claim, wherein each flexible layer has a thickness between 0.2mm and 0.5mm.

11. A protective material according to any preceding claim, wherein said fibres

have a denier between 400 and 1500.

12. A protective material according to any preceding claim, further including at least one layer containing ceramic plates.

13. A protective material according to any preceding claim, wherein the support material has sufficient rigidity to enable the or each flexible layer to support its own weight.

14. A garment made at least partly from a protective material according to any preceding claim.

15. A garment according to claim 14, comprising a vest or jacket.

16. A garment according to claim 14 or 15, wherein the protective material is provided in the form of a pack that can be removably secured to the garment.

17. Headwear made at least partly from a protective material according to any one of claims 1 to 13.

18. Footwear made at least partly from a protective material according to any one of claims 1 to 13.

19. A protective material substantially as herein described.

ABSTRACT (FOR GB-B-2304350)

PROTECTIVE MATERIAL

A protective material has at least one flexible layer comprising a plurality of fibres capable of resisting penetration by a bullet or knife, and a support material. The fibres are at least partially embedded within the support material to restrict relative movement of the fibres therein.